

## PLANT ITEM MATERIAL SELECTION DATA SHEET



## TLP-RBLR-00001 (PTF)

## Treated LAW Evaporator Reboiler

- Design Temperature (°F) (max/min): Shell side: 275/49; Tube side: 175/49
- Design Pressure (psig) (max/min): Shell side: 50/FV; Tube side: 50/FV
- Location: incell

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RPP-WTP PDC

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Operating conditions are as stated on attached Process Corrosion Data Sheet

## Options Considered:

- pH between 12 and 14; halide concentrations similar to TLP-SEP-00001; operating temperature 122 °F

## Materials Considered:

Material (UNS No.)	Acceptable Material	Unacceptable Material
Carbon Steel		X
304L (S30403)	X	
316L (S31603)	X	
6% Mo (N08367/N08926)	X	
Alloy G-30 (N06030)	X (heat exchange surfaces)	
Alloy 22 (N06022)	X	
Ti-2 (R50400)		X

Recommended Material: Shell: 304 (max 0.030% C; dual certified)

Tubes and related heated surfaces: N06030 (G-30 or equivalent)

Recommended Corrosion Allowance: Tube side: 0.04 inch (includes 0.024 inch corrosion allowance and 0.004 inch erosion allowance)

Shell side: 0.0 inch

## Process &amp; Operations Limitations:

- Develop flushing/rinsing procedure for acid or water



EXPIRES: 12/07/07

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## PLANT ITEM MATERIAL SELECTION DATA SHEET

### Corrosion Considerations:

#### a General Corrosion

Hammer's data (1981), 304 (and 304L) lists a corrosion rate in NaOH of less than 20 mpy (500  $\mu\text{m}/\text{y}$ ) at 77°F and over 20 mpy at 122°F. He shows 316 (and 316L) has a rate of less than 2 mpy up to 122°F and 50% NaOH. Dillon (2000) and Sedriks (1996) both state that the 300 series stainless steels are acceptable in up to 50% NaOH at temperatures up to about 122°F or slightly above. Divine's work (1986) with simulated-radwaste evaporators, six months at 140°F, showed 304L was slightly more resistant to corrosion (<0.2 mpy) than was 316L (<0.6 mpy); Ni 200, pure nickel, was much less resistant ( $\approx 7$  mpy) probably due to the complexants.

Davis (1994) states the corrosion rate for 304L in pure NaOH will be less than about 0.1 mpy up to about 212°F though Sedriks states the data above 122°F are incorrect. Danielson & Pitman (2000), based on short-term studies, suggest a corrosion rate of about 0.5 mpy for 316L in simulated waste at boiling.

Ohl & Carlos (1994) found, in their review of the 242-A Evaporator with waste similar to that expected in LAW, the corrosion of 304L was less than the accepted variability of the plate thickness after two years of operation at 140°F. Because of uncertainties of the starting wall thickness, a review of the raw data was inconclusive. 304L appears have corroded at an average rate of about 10 mpy though it may have been higher or lower.

Uhlig (1948) has shown that pure nickel is more resistant to corrosion by NaOH than stainless steel. However, as Divine (1986) pointed out, the presence of complexing agents may reverse the trend. Agarwal (2000) states that the higher nickel alloys, such as C-22 and G-30, are highly corrosion resistant though specific mention of alkaline media is not made. The general literature mainly discusses cracking problems (see below) rather than uniform corrosion.

Zapp (1998) notes that the evaporator vessels at Savannah River Site are made of 304L and have suffered no failures in over 30 years of operation. Savannah River uses G-3 and G-30 alloys for the evaporator tubes.

The shell side, however, will see only steam and 304L is satisfactory.

#### Conclusion:

For the shell, it appears that 304L is acceptable.

#### b Pitting Corrosion

Chloride is notorious for causing pitting in acid and neutral solutions. Dillon (2000) is of the opinion that in alkaline solutions, pH>12, chlorides are likely to promote pitting only in tight crevices. Dillon and Koch (1995) are of the opinion that fluoride will have little effect. Jenkins (1998) has stated that localized corrosion can occur under the deposits on tubes, probably due to the chlorides.

Revie (2000) and Uhlig (1948) note that nitrate inhibits chloride corrosion. Therefore, the high nitrate concentrations in the LAW are expected to be beneficial.

The apparent lack of pitting in the 242-A Evaporator suggests 304L is acceptable at the design conditions. Zapp (1998) confirms the behavior of 304L in the shell. Use of austenitic alloys is not recommended for the tubes.

Based on tests performed by Divine (1986), 304L would be satisfactory for the tubes. However, if it is assumed the temperature can approach low pressure steam temperatures, then, based on Savannah River data, a higher alloy is recommended for the tubes. Some of the data described above suggest that a high chromium and perhaps molybdenum content will be needed. G-30 alloy, based on the current Savannah River experience, can be selected.

The higher nickel and molybdenum alloys are expected to be more pitting resistant than the austenitic alloys. Because high purity nickel, Ni 200, did not fare well in Divine's tests (1986) in the presence of complexants, but the chromium content of the alloys may mitigate that effect. Jenkins (1998) reports that G3 and G30 evaporator tubes have been used successfully at Savannah River Site for over 10 years and they expect at least 20 years service while 304L had failed after about 10 years. The shell of the evaporator has performed successfully for approximately 30 years.

#### Conclusion:

Localized corrosion, such as pitting, is common but probably can be mitigated by alloys with higher nickel and molybdenum contents even under heat transfer conditions or where deposits can form. Based on Savannah River data, the shell is expected to be free of significant corrosion and can be 304L.

#### c End Grain Corrosion

End grain corrosion only occurs in metal with exposed end grains and in highly oxidizing acid conditions.

#### Conclusion:

Not applicable to this system.

## PLANT ITEM MATERIAL SELECTION DATA SHEET

### d Stress Corrosion Cracking

The exact amount of chloride required to stress corrosion crack stainless steel is unknown. In part, this is because the amount varies with temperature, metal sensitization, and the environment. But it is also unknown because chloride tends to concentrate under heat transfer conditions, by evaporation, and electrochemically during a corrosion process. Hence, even as little as 10 ppm can lead to cracking under some conditions. Generally, as seen in Sedriks (1996) and Davis (1987), stress corrosion cracking does not usually occur below about 140°F. Further, the use of "L" grade stainless reduces the opportunity for sensitization. From the above references, it also observed that alkaline conditions reduce the probability of the initiation of stress corrosion cracking to essentially zero. However, should a pit or crevice, including a deposit, be present where the environment can become acid, then the alkaline environment will no longer have an effect and stress corrosion can occur.

Caustic cracking tends to occur below 140°F (Sedriks 1996; Dillon, 2000) or below 212°F (Zapp 1998). Because the normal operating temperature is below 140°F, all sources suggest caustic cracking should be minimal. Zapp's data from the Savannah River Site evaporators is auspicious for the use of 304L for the shell. If the 140°F temperature is exceeded, such as on the evaporator tubes, higher alloys are needed.

#### *Conclusion:*

The use of 304L is expected to be acceptable for the shell at the stated operating temperature. The tubes should be a higher alloy, such as G-30.

### e Crevice Corrosion

See Pitting.

#### *Conclusion:*

See Pitting

### f Corrosion at Welds

Weld corrosion is not considered a problem in the proposed environment.

#### *Conclusion:*

Weld corrosion is not considered a problem for this system.

### g Microbiologically Induced Corrosion (MIC)

MIC is normally observed at lower pH conditions and temperatures. Although microbes can live at very low pH, and probably high pH, as well as at 572°F and in radiation fields, no reports of MIC in the proposed conditions have been reported.

#### *Conclusion:*

MIC is not considered a problem.

### h Fatigue/Corrosion Fatigue

Corrosion fatigue is not considered a problem.

#### *Conclusions:*

Not a concern.

### i Vapor Phase Corrosion

The vapor phase portion of the tank will be continually washed with condensing vapors and periodically sprayed with wash water via the vessel wash rings while also being spattered with caustic.

#### *Conclusion:*

Based on Zapp's work (1998), no vapor phase corrosion is anticipated.

### j Erosion

Velocities within the reboiler are expected to be low. Erosion allowance of 0.004 inch for components with low solids content (< 2 wt%) at low velocities is based on 24590-WTP-RPT-M-04-0008.

#### *Conclusion:*

Not a concern.

### k Galling of Moving Surfaces

Not applicable.

#### *Conclusion:*

Not applicable.

**PLANT ITEM MATERIAL SELECTION DATA SHEET****l Fretting/Wear**

Not anticipated to be a problem.

*Conclusion:*

Not expected to be a concern.

**m Galvanic Corrosion**

For the environment and the proposed alloys, none expected.

*Conclusion:*

Not a concern.

**n Cavitation**

Not applicable.

*Conclusion:*

Not applicable.

**o Creep**

Not a concern at the given temperatures and at the given pressures.

*Conclusion:*

Not applicable.

**p Inadvertent Addition of Nitric Acid**

Higher chloride contents and higher temperatures usually require higher alloy materials. Nitrate ions inhibit the pitting and crevice corrosion of stainless alloys. Furthermore, nitric acid passivates these alloys; therefore, lower pH values brought about by increases in the nitric acid content of process fluid will not cause higher corrosion rates for these alloys. The upset condition that was most likely to occur is lowering of the pH of the vessel content by inadvertent addition of 0.5 M nitric acid. Lowering of pH may make a chloride-containing solution more likely to cause pitting of stainless alloys. Increasing the nitric acid content of the process fluid adds more of the pitting-inhibiting nitrate ion to the process fluid. In addition, adding the nitric acid solution to the stream will dilute the chloride content of the process fluid.

*Conclusion:*

The recommended materials will be able to withstand a plausible inadvertent addition of 0.5 M nitric acid for a limited period.

## PLANT ITEM MATERIAL SELECTION DATA SHEET

## References:

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2. 24590-WTP-RPT-PR-04-0001, Rev. B, *WTP Process Corrosion Data*
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5. Agarwal, DC, *Nickel and Nickel Alloys*, In: Revie, WW, 2000. *Uhlig's Corrosion Handbook*, 2nd Edition, Wiley-Interscience, New York, NY 10158
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## Bibliography:

1. CCN 130170, Blackburn, LD to PG Johnson, Internal Memo, Westinghouse Hanford Co, *Evaluation of 240-AR Chloride Limit*, August 15, 1991.
2. CCN 130171, Ohl, PC to PG Johnson, Internal Memo, Westinghouse Hanford Co, *Technical Bases for Cl- and pH Limits for Liquid Waste Tank Cars*, MA: PCO:90/01, January 16, 1990.
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4. Smith, HD and MR Elmore, 1992, *Corrosion Studies of Carbon Steel under Impinging Jets of Simulated Slurries of Neutralized Current Acid Waste (NCAW) and Neutralized Cladding Removal Waste (NCRW)*, PNL-7816, Pacific Northwest Laboratory, Richland, Washington.
5. Van Delinder, LS (Ed), 1984, *Corrosion Basics*, NACE International, Houston, TX 77084

## PLANT ITEM MATERIAL SELECTION DATA SHEET

24590-WTP-RPT-PR-04-0001, Rev. B

WTP Process Corrosion Data

## PROCESS CORROSION DATA SHEET

Component(s) (Name/ID #) Waste feed evaporator separator (TLP-SEP-00001)  
Treated LAW evaporator reboiler (TLP-RBLR-00001)

Facility PTF

In Black Cell? Yes (TLP-SEP-00001 only)

Chemicals	Unit <sup>1</sup>	Contract Maximum		Non-Routine		Notes
		Leach	No leach	Leach	No Leach	
Aluminum	g/l	3.85E+01	3.52E+01			
Chloride	g/l	1.83E+01	2.00E+01			
Fluoride	g/l	1.84E+01	2.01E+01			
Iron	g/l	2.83E+00	2.89E+00			
Nitrate	g/l	2.72E+02	2.88E+02			
Nitrite	g/l	8.19E+01	8.89E+01			
Phosphate	g/l	5.91E+01	6.28E+01			
Sulfate	g/l	3.15E+01	3.42E+01			
Mercury	g/l	8.96E-01	3.14E-02			
Carbonate	g/l	1.27E+02	1.10E+02			
Undissolved solids	wt%					
Other	g/l					
Other	g/l					
pH	N/A					Note 3
Temperature	°F					Note 2
List of Organic Species:						
References						
System Description: 24590-PTF-3YD-TLP-00001, Rev 0						
Mass Balance Document: 24590-WTP-M4C-V11T-00005, Rev A						
Normal Input Stream #: TLP13, TLP02, CXP23						
Off Normal Input Stream # (e.g., overflow from other vessels): FRP03, LFP08						
P&ID: 24590-PTF-M6-TLP-P0003, Rev 0						
PFD: 24590-PTF-M5-V17T-P0005, Rev 0						
Technical Reports:						
Notes:						
1. Concentrations less than $1 \times 10^{-4}$ g/l do not need to be reported; list values to two significant digits max.						
2. T normal operation 122 °F (24590-PTF-MVC-TLP-00002, Rev B)						
3. pH approximately 12 to 14						
Assumptions:						

**PLANT ITEM MATERIAL SELECTION DATA SHEET****24590-WTP-RPT-PR-04-0001, Rev. B**  
**WTP Process Corrosion Data****4.13.2 Treated LAW Evaporator Reboiler (TLP-RBLR-00001)****Routine Operations**

Two streams are fed into the treated LAW evaporator at the suction side of the recirculation pump (TLP-PMP-00001). First, the treated LAW is transferred from one of the three treated LAW collection vessels at a fixed flow rate. Second, the LAW SBS condensate/recycle stream is transferred from one of the LAW SBS vessels (TLP-VSL-00009A or B) using the variable-speed LAW SBS condensate feed pumps (TLP-PMP-00005A/B).

The recirculation pump moves the liquor through the evaporator recirculation loop maintaining a high flow rate through the evaporation system. First, the liquor is pumped through the treated LAW evaporator reboiler (TLP-RBLR-00001), which raises the temperature of the liquor. Recirculating liquor is prevented from boiling in the reboiler tubes by maintaining sufficient hydrostatic head to increase the boiling point above the temperature of the liquor in the reboiler. Low-pressure steam, modulated via a flow controller, will be used to heat the feed liquor to the selected system boil-off rate. Low-pressure steam is available at 40 psig and 286 °F, from the *Basis of Design* (24590-WTP-DB-ENG-01-001).

**Non-Routine Operations that Could Affect Corrosion/Erosion**

High solids in evaporator.